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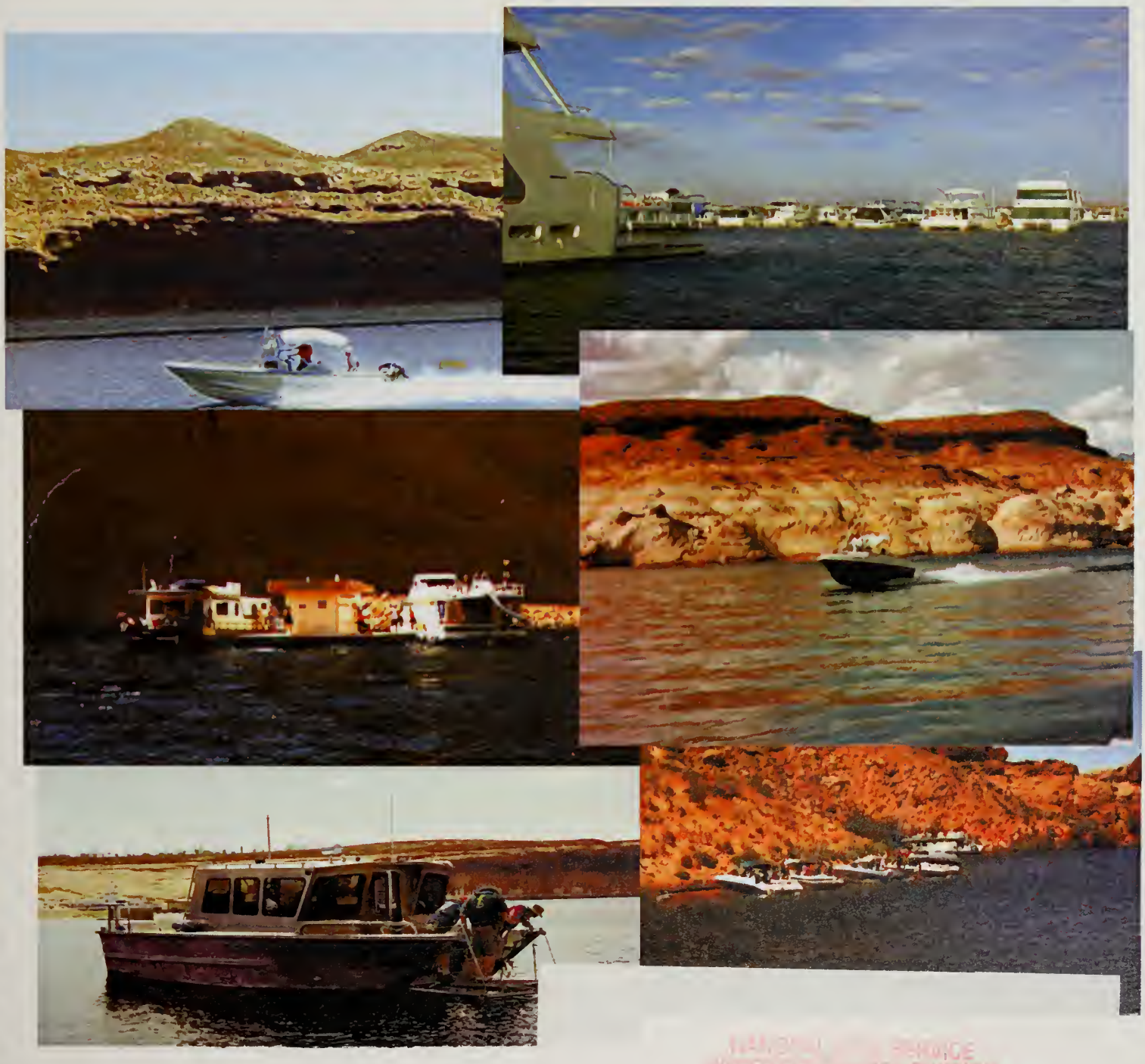
*GLCA, LAME

A Monitoring Plan for the Occurrence of Hydrocarbon Constituents in Lakes Powell, Mead, and Mohave—Arizona, Nevada, and Utah

Prepared in cooperation with the National Park Service



2004

DIVISION
COLORADO

A Monitoring Plan for the Occurrence of Hydrocarbon Constituents in Lakes Powell, Mead, and Mohave—Arizona, Nevada, and Utah

Final

Prepared in cooperation with the National Park Service

Tucson, Arizona
2004

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DEFINITION OF ABBREVIATIONS AND ACRONYMS

EIS	environmental impact statement
GC/MS	gas chromatography-mass spectrometry
GLCA	Glen Canyon National Recreation Area
LAME	Lake Mead National Recreation Area
MCL	Maximum Contaminant Level
MTBE	methyl tert-butyl ether
NAWQA	National Water Quality Assessment Program
NEPA	National Environmental Policy Act
NPS	National Park Service
NRA	National Recreation Area
NWQL	USGS National Water Quality Laboratory
PAH	polycyclic aromatic hydrocarbon
PTFE	polytetrafluroethylene
PWC	personal watercraft
PVC	polyvinyl chloride
ROD	Record of Decision
SPMD	semipermeable membrane devices
SVOC	semivolatile organic compound
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

INTRODUCTION

The National Park Service (NPS) provides the stewardship and management of Lake Powell (Glen Canyon National Recreation Area; GLCA) and Lakes Mead and Mohave (Lake Mead National Recreation Area) on the Colorado River in Utah, Arizona, and Nevada (fig. 1). These lakes are intensively used for recreational boating. More than 830,000 recreational visitor days of boating occurred on Lake Powell in 2002, and more than 375,000 total boat trips occurred on Lakes Mead and Mohave in 2002 (table 1). Many recreational watercraft are equipped with carbureted, 2-stroke engines that can degrade water quality by releasing large amounts of uncombusted fuel and oil, fuel-related compounds (such as benzene, toluene, ethylbenzene, and xylenes), and products of incomplete fuel combustion (such as polycyclic aromatic hydrocarbons). One study indicates carbureted, 2-stroke engines can discharge as much as 30 percent of their fuel directly to water bodies (California Environmental Protection Agency-Air Resources Board, 1999).

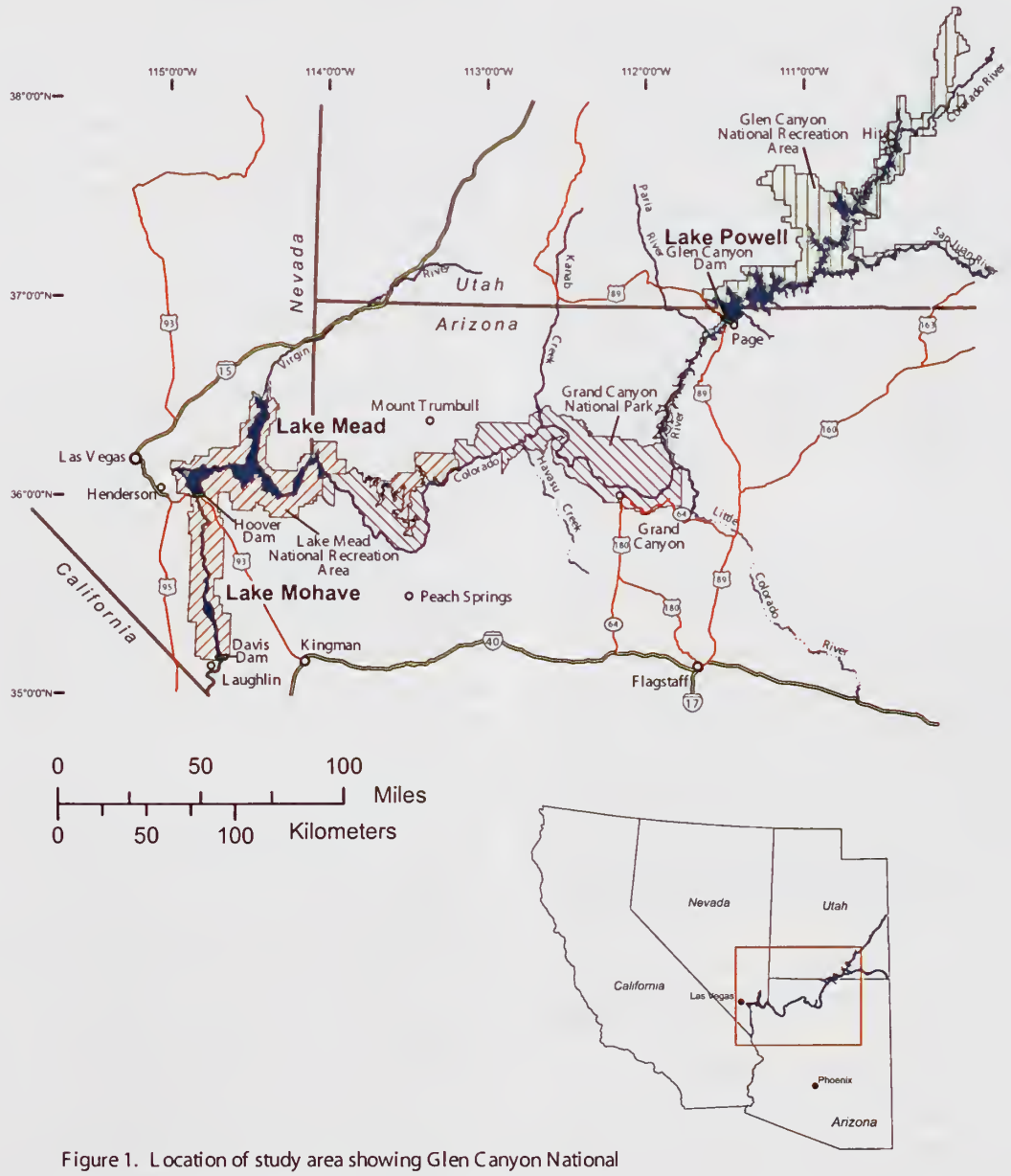


Figure 1. Location of study area showing Glen Canyon National Recreation Area and Lake Mead National Recreation Area.

Table 1. Estimated frequency of use by watercraft and engine type, Lake Powell, Utah and Arizona, and Lake Mead and Lake Mohave, Nevada and Arizona, 2002

[Percentage of use, by engine type, shown in parentheses]

Watercraft and engine type	Lake Powell boat days[1]	Lake Mead boat trips[2]	Lake Mohave boat trips[2]
Boat, outboard engine			
Carbureted, 2-stroke	50,696 (6.1)	8,979 (4.8)	11,712 (8.4)
Direct injection, 2-stroke	19,115 (2.3)	5,007 (2.7)	1,599 (1.1)
EFT, 2-stroke	19,115 (2.3)	5,007 (2.7)	1,599 (1.1)
Carbureted or EFI, 4-stroke	39,061 (4.7)	10,015 (5.3)	3,198 (2.3)
Inboard/stern drive			
Carbureted or EFI, 4-stroke	434,654 (52.3)	98,344 (52.3)	35,502 (25.4)
Inboard jet gas, 4-stroke	24,932 (3.0)	5,591 (3.0)	8,702 (6.2)
Outboard/auxiliary sail			
Carbureted, 4-stroke/Diesel	13,297 (1.6)	3.096 (1.6)	0 (0.0)
Personal watercraft			
Carbureted, 2-stroke	99,459 (24.0)	35,318 (18.8)	50,978 (36.5)
Direct injection, 2-stroke	14,959 (1.8)	8,286 (4.4)	13,176 (9.4)
4-stroke	14,959 (1.8)	8,286 (4.4)	13,176 (9.4)
Total	830,247	187,931	139,640

[1]National Park Service, 2003a
[2]National Park Service, 2003b

In May 1998, the Bluewater Network, a coalition of more than 70 organizations, petitioned the NPS to prohibit personal watercraft (PWC) use throughout the national park system. In response to the Bluewater Network petition, the NPS issued a final regulation in March 2000 that prohibits use of PWCs in most park units and allowed PWC use in 21 units that were to determine appropriate local conditions for continued PWC use. The Bluewater Network filed a lawsuit against the NPS to challenge the decision allowing continued PWC use in the 21 park units. Under terms of a negotiated settlement of this lawsuit, the NPS agreed to implement a special regulation for each park unit to manage or discontinue PWC use and evaluate the decision for each special regulation according to the National Environmental Policy Act (NEPA).

Glen Canyon and Lake Mead National Recreation Areas (NRA) are among the first park units to address requirements for long-term PWC use. Each park unit has prepared an environmental impact statement evaluating the effects of future PWC-use scenarios and has enacted park-specific rules for continued PWC use. Each park will prohibit PWC use in environmentally sensitive areas, prohibit or restrict PWC use in areas near shorelines, eventually ban PWC with carbureted 2-stroke engines, and implement environmental monitoring programs to evaluate the effects of long-term PWC use on natural resources.

The NPS and the Glen Canyon and Lake Mead NRAs require a water-quality monitoring plan for fuel and fuel-related combustion compounds that employs consistent methodologies in Lakes Powell, Mead, and Mohave. This monitoring plan will allow the NPS and the two park units to collect sufficient data needed to evaluate the effectiveness of the new rules allowing long-term PWC use in most areas of the lakes and provide park managers with information to protect and enhance aquatic ecosystems. This monitoring plan also may provide a template for other park units that are developing similar rules to allow long-term PWC use.

Previous Investigations

Little water-quality monitoring data on fuel and fuel-based combustion compounds exists for Glen Canyon or Lake Mead NRAs. Most data collected to date were for focused studies of short duration. By using semipermeable membrane devices, Bevans and others (1996) detected numerous polycyclic aromatic hydrocarbons (PAHs) in bottom-sediment samples and in the water columns at several locations on Lake Mead, and associated the occurrence of these compounds to the discharge of wastewater and urban runoff from Las Vegas Valley. In June 1999, five water samples were collected at 1-m depths near marinas and boat ramps at both Lake Mead and Lake Mohave. Analysis of these samples indicated that BTEX compounds (benzene, toluene, ethylbenzene, and xylenes) and MTBE (methyl tert-butyl ether, a fuel oxygenate) were present at all sampling sites in both lakes (Robert A. Boyd, hydrologist, USGS, written commun., July 2003). Covay and Beck (2001) detected numerous PAHs and other semivolatile compounds in intervals of coring samples collected from several sites in Las Vegas Bay in Lake Mead. Hart and others (in review) detected fuel-related compounds, including BTEX compounds, MTBE, and oil and grease, in water samples collected from three side canyons on Lake Powell. The USGS retrieved sediment cores in 2001

from the delta area of Lake Powell formed by the Colorado River that showed concentrations of numerous parent PAHs and multiple alkyl-PAH isomers in selected subsamples. Additional analysis and evaluation of these samples are currently being done by the USGS (Robert J. Hart, hydrologist, and Howard E. Taylor, chemist, USGS, in preparation). During the summer of 2001, the NPS in cooperation with the State of Utah and the USGS, collected and analyzed several water samples from marinas and selected side canyons of Lake Powell for hydrocarbon contamination (Mark VanMouwerik, hydrologist, NPS, written commun., July 2001). These data provided the NPS with a snapshot of hydrocarbon concentrations during the time of collection.

Passive semipermeable membrane devices (SPMDs) have been used in many studies to simulate bioassimilation and assess the occurrence of semivolatile synthetic organic compounds in water. Shigenaka and Henry (1995) used SPMDs to monitor the bioaccumulation of hydrocarbons in mussels after the Exxon Valdez oil spill in Alaska; Bevans and others (1996) deployed several SPMDs in Lake Mead as part of a study of carp endocrinology and histology; Bastian and others (1997) used SPMDs during a study of organochlorine pesticides in areas of the Mississippi River delta; Lico and Pennington (1999) used SPMDs as part of a study of synthetic organic compounds in Lake Tahoe. The NPS also is currently engaged in a study that uses passive SPMDs for assessing the presence and potential impacts of PAHs resulting from recreational snowmobile use in Rocky Mountain and Voyageurs National Parks (Gary Rosenlieb, hydrologist, NPS, written commun., February 18, 2004).

Environmental Setting and Description

Glen Canyon NRA encompasses an area of about 0.5 million ha (1.25 million acres) along the Colorado River in northern Arizona and southern Utah and includes Lake Powell (fig. 1). More than 2 million people visit Glen Canyon NRA each year. Lake Powell has a surface area of about 24,800 ha (61,390 acres) and a storage capacity of about 32.3 million m^3 (26.2 million acre-ft) at full pool elevation. The maximum depth of water at the dam is about 182 m (600 ft). The lake has more than 3,050 km (1,900 mi) of shoreline, with numerous side channels and canyons. Average annual precipitation near the lake is about 6 in. Air temperatures can range from 0°C in winter months to 44°C in summer months.

The Lake Mead NRA also encompasses an area of more than 0.5 million ha (1.5 million acres) in southern Nevada and northwestern Arizona, and includes Lake Mead, Lake Mohave, and a reach of the Colorado River (fig. 1). More than 9 million people visit Lake Mead NRA each year. Lake Mead is the largest freshwater reservoir, by volume, in the United States. It has a surface area of about 63,900 ha (158,000 acres) and a storage capacity of about 35.1 million m^3 (28.5 million acre-ft) at full pool elevation. The maximum depth of water at the dam is about 150 m (500 ft). Lake Mead has about 880 km (550 mi) of shoreline and is divided into four main basins—Boulder, Virgin, Temple, Gregg, and the Overton Arm.

Lake Mohave is narrow and extends about 20 km (65 mi) downstream from the much larger Lake Mead; it has a surface area of about 11,300 km^2 (28,000 acres) and a storage capacity of about 2.2 million m^3 (1.8 million acre-ft) at full pool elevation.

Average annual precipitation near Lakes Mead and Mohave is less than 4 in. Air temperatures can range from less than 0°C in winter months to more than 46°C in summer months.

Purpose and Scope

The overall purpose of this monitoring plan is to present a sampling and analysis approach that will provide the NPS with representative data on the occurrence of hydrocarbon compounds in waters of Lakes Powell, Mead, and Mohave within Glen Canyon NRA and Lake Mead NRA. The monitoring plan identifies locations for collecting samples, frequencies of sample collection, affected sampling media, and target constituent compounds.

Regulatory Framework

General provisions of the Organic Act of 1916 direct the NPS to provide stewardship over national park units to insure that natural resources within these areas are not impaired by development and are available for the enjoyment of future generations.

Enabling legislation established Glen Canyon NRA and Lake Mead NRA for the general purposes of public recreation, benefit, and use in a manner that will preserve the features of these areas. The discharge of pollutants to waters within Glen Canyon and Lake Mead NRAs is regulated under the Clean Water Act. Application of the Clean Water Act for regulating the discharge of hydrocarbons from motorized watercraft could be limited because watercraft are non-point sources of pollution. The Safe Drinking Water Act applies to the finished water supply at the tap and, therefore, this act has no direct regulatory effect on ambient water of the reservoirs. The States can set standards, however, for ambient conditions of the reservoir waters for drinking-water constituents or for biological quality. Provisions of the Endangered Species Act prohibit the impairment of aquatic habitats that support Federal-listed species. Lake Powell and its tributary inflows are designated critical habitat for four endangered fish species: the Colorado pike minnow, razorback sucker, bonytail chub, and humpback chub. Lake Mead is designated critical habitat for the razorback sucker. Lake Mohave is designated critical habitat for the razorback sucker and bonytail chub. Glen Canyon NRA manages Lake Powell and its tributary inflows in accordance with state regulations promulgated by Arizona and Utah. Lake Mead NRA manages Lake Mead and Lake Mohave in accordance with state regulations promulgated by Nevada and Arizona. Utah, Arizona, and Nevada each have antidegradation policies regarding the beneficial uses associated with water resources.

DESCRIPTION OF CONTAMINANTS, METHODS, AND APPROACH

It has been estimated that personal watercraft engines (especially carbureted 2-stroke versions) and other combustion-powered watercraft, discharge up to 30 percent of their consumed gasoline and oil as uncombusted constituents into the surrounding surface water during operation. In sufficient concentrations, these constituents may adversely affect the ecosystem and, potentially, the health of individuals exposed to the emissions. Chemical constituents of particular concern include the groups of chemicals known as volatile organic compounds (VOCs) and PAHs.

VOCs are a class of chemicals that have important properties in common: they evaporate, or vaporize, readily (they are volatile), and they contain carbon. They have chemical and physical properties that allow them to move freely between water and air. In general, these compounds have low molecular weights, high vapor pressures, and low-to-medium water solubility (Rathbun, 1998). VOCs have been used extensively in industry, commerce, and households in the United States since the 1940s. Many products contain these compounds, including fuels, solvents, paints, glues, adhesives, deodorizers, refrigerants, and fumigants. Large quantities of VOCs are released to the environment as indicated by reports completed by commercial and industrial entities as part of the 1996 Toxics Release Inventory (U.S. Environmental Protection Agency, 1998). Data in this inventory show that 10 of the top 20 chemical compounds with the largest releases to the environment were VOCs, with combined VOC releases of almost 2.2 trillion kg (1 trillion lbs) in 1996.

The U.S. Environmental Protection Agency (USEPA) estimates that one-fifth of the nation's water supply contains VOCs. Table 2 lists predominant sources for some VOCs commonly detected in water supplies. Benzene, for example, may enter water from gasoline or oil spills, or from leaking fuel tanks. Other examples of commonly detected VOCs are dichloromethane (methylene chloride), an industrial solvent; trichloroethylene, used in septic system cleaners; and tetrachloroethylene (perchloroethylene), used in the dry-cleaning industry.

Fossil fuels and lubricants, such as gasoline and motor oils, consist of a solution of highly volatile light hydrocarbons (VOCs), and heavier semivolatile hydrocarbons. The VOCs consist of benzene, toluene, ethylbenzene, and xylene (BTEX compounds). Xylene can be expressed either as total xylene or its individual isomers (m-xylene, o-xylene and p-xylene). In addition to these compounds, oxygenated fuel additives are used to improve the combustion characteristics of the gasoline and increase the octane rating (Grady, 2003). Common additives include ethanol, methanol, and MTBE. Although the alcohols do not present a significant environmental problem, MTBE can be an important contaminant (Delzer and Ivahnenko, 2003a and 2003b).

Table 2. Volatile organic compounds and their predominant uses (adapted from Rathbun, 1998, and Bender and others, 1999)

[IUPAC, International Union of Pure and Applied Chemistry. Dashes indicate no data]

IUPAC name	Select alternative name	Predominant use	Chemical formula
Halogenated alkanes			
Bromodichloromethane	--	Organic synthesis	$CHBrCl_2$
Bromomethane1	Methyl bromide	Fumigant	CH_3Br
Chlorodibromomethane	--	Organic synthesis	$CHBr_2Cl$
Chloroethane	Ethyl chloride	Solvent	C_2H_5Cl
Chloromethane1	Methyl chloride	Refrigerant	CH_3Cl
1,2-dibromo-3-chloropropane	DBCP	Fumigant	$C_3H_5Br_2Cl$
1,2-dibromoethane	EDB	Fumigant	$C_2H_4Br_2$
Dichlorodifluoromethane	Freon 12, CFC 12	Refrigerant	CCl_2F_2
1,1-dichloroethane	Ethylidenedichloride	Solvent	$C_2H_4Cl_2$
1,2-dichloroethane	Ethylenedichloride	Solvent	$C_2H_4Cl_2$
Dichloromethane	Methylene chloride	Solvent	CH_2Cl_2
1,2-dichloropropane	--	Solvent	$C_3H_6Cl_2$
Hexachloroethane	--	Metallurgy refining	C_2Cl_6
Tetrachloromethane	Carbon tetrachloride	Solvent	CCl_4
Tribromomethane	Bromoform	Solvent	$CHBr_3$
Trichloromethane	Chloroform	Solvent	$CHCl_3$
1,1,1-trichloroethane	Methyl chloroform	Solvent	$C_2H_3Cl_3$
1,1,2-trichloroethane	--	Solvent	$C_2H_3Cl_3$
Trichlorofluoromethane	Freon 11, CFC 11	Refrigerant	CCl_3F
1,2,3-trichloropropane	--	Solvent	$C_3H_5Cl_3$
1,1,2-trichloro-1,2,2-trifluoroethane	Freon 113, CFC 113	Refrigerant	$C_2Cl_3F_3$
Bromoethene	Vinyl bromide	Fire retardant	C_2H_3Br
Chloroethene	Vinyl chloride	Organic synthesis	C_2H_3Cl
1,1-dichloroethene	--	Organic synthesis	$C_2H_2Cl_2$
cis-1,2-dichloroethene	--	Solvent	$C_2H_2Cl_2$
trans-1,2-dichloroethene	--	Solvent	$C_2H_2Cl_2$
cis-1,3-dichloropropene	--	Fumigant	$C_3H_4Cl_2$
trans-1,3-dichloropropene	--	Fumigant	$C_3H_4Cl_2$
Hexachlorobutadiene	--	Organic synthesis	C_4Cl_6
Tetrachloroethene	Tetrachloroethylene, perchloroethylene, PCE	Solvent	C_2Cl_4
Trichloroethene	Trichloroethylene, TCE	Solvent	C_2HCl_3
Aromatic hydrocarbons			
Benzene	--	Gasoline aromatic hydrocarbon	C_6H_6
Naphthalene	--	Gasoline aromatic hydrocarbon	$C_{10}H_8$
Styrene	Vinyl benzene	Organic synthesis	C_8H_8

Table 2. Continued

IUPAC name	Select alternative name	Predominant use	Chemical formula
	Alkyl benzenes		
n-butylbenzene	--	Gasoline aromatic hydrocarbon	$C_{10}H_{14}$
1,2-dimethylbenzene	O-Xylene	Gasoline aromatic hydrocarbon	C_8H_{10}
1,3-dimethylbenzene	M-Xylene	Gasoline aromatic hydrocarbon	C_8H_{10}
1,4-dimethylbenzene	P-Xylene	Gasoline aromatic hydrocarbon	C_8H_{10}
Ethylbenzene	--	Gasoline aromatic hydrocarbon	C_8H_{10}
Methylbenzene	Toluene	Gasoline aromatic hydrocarbon	C_7H_8
iso-propylbenzene	Cumene	Organic synthesis	C_9H_{12}
n-propylbenzene	--	Solvent	C_9H_{12}
1,2,4-trimethylbenzene	--	Organic synthesis	C_9H_{12}
	Halogenated aromatics		
Chlorobenzene	--	Solvent	C_6H_5Cl
1,2-dichlorobenzene	o-dichlorobenzene	Solvent	$C_6H_4Cl_2$
1,3-dichlorobenzene	m-dichlorobenzene	Solvent	$C_6H_4Cl_2$
1,4-dichlorobenzene	p-dichlorobenzene	Fumigant	$C_6H_4Cl_2$
1,2,3-trichlorobenzene	--	Organic synthesis	$C_6H_3Cl_3$
1,2,4-trichlorobenzene	--	Solvent	$C_6H_3Cl_3$
	Ethers		
tert-amyl methyl ether	TAME	Oxygenate	$C_6H_{14}O$
diisopropyl ether	DIPE	Oxygenate	$C_6H_{14}O$
Ethyl tert-butyl ether	ETBE	Oxygenate	$C_6H_{14}O$
Methyl tert-butyl ether	MTBE	Oxygenate	$C_5H_{12}O$
	Others (aldehydes and nitriles)		
2-propenal	Acrolein	Organic synthesis	C_3H_4O
2-propenenitrile	Acrylonitrile	Organic synthesis	C_3H_3N

Semivolatile organic compounds (SVOCs) or PAHs are common contaminants in freshwater systems (Eisler, 1987; Johnson and others, 1985). Sources such as oil spills, industrial effluent, urban runoff, and atmospheric deposition are thought to be the primary origin of these compounds in ecosystems. Owing to their high degree of aromaticity, PAH compounds are extremely stable and thus highly persistent in the environment. The fate of these compounds is of significant environmental concern because of their acute carcinogenic toxicity (Anderson and others, 1974) and their substantial persistence once they enter the ecosystem. Because of their hydrophobic character, PAHs tend to accumulate in sediments. PAHs also can be found partitioned between the water column and aquatic organisms; however, concentrations in these materials are many orders of magnitude less than those obseved in sediments. High concentrations of PAHs around marinas and other areas with extensive motorboat activity probably are the result of motor exhaust and fuel/oil spills (Smith and others, 1985; Marcus and others, 1988). It is, therefore, reasonable to expect these compounds to be present in areas with high usage of recreational watercraft.

PAHs are organic compounds that contain two to five aromatic rings. Conventionally, PAHs do not include the lighter compounds that contain only one aromatic ring, such as the BTEX compounds, which are highly volatile. Generally, PAHs have their aromatic rings fused together; however, compounds such as biphenyl are also considered PAHs even though it has two aromatic rings joined together rather than fused. Some of the more than 100 separate known PAHs are shown in table 3.

Table 3. Selected polycyclic aromatic hydrocarbon compounds (PAHs)

Acenaphthene
Acenaphthylene
Anthracene
Anthracenes, (monomethylated isomers)
Anthracenes, (dimethylated isomers)
Anthracenes, (trimethylated isomers)
Anthracenes, (higher substituted isomers)
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Benzo(e)pyrene
Benzo(a)pyrene
Biphenyl
Chrysene
Chrysenes, (monomethylated isomers)
Chrysenes, (dimethylated isomers)
Chrysenes, (trimethylated isomers)
Chrysenes, (higher substituted isomers)
Dibenzo(a,h)anthracene
Dibenzothiophene
Dibenzothiophenes, (monomethylated isomers)
Dibenzothiophenes, (dimethylated isomers)
Dibenzothiophenes, (trimethylated isomers)
Fluoranthene
Fluoranthenes, (monomethylated isomers)
Fluoranthene, 1-methyl
Fluorene
Fluorenes, (monomethylated isomers)
Fluorenes, (dimethylated isomers)
Fluorenes, (trimethylated isomers)
Ideno(1,2,3,c,d)pyrene
Naphthalene
Naphthalenes, (monomethylated isomers)
Naphthalenes, (dimethylated isomers)
Naphthalenes, (trimethylated isomers)
Naphthalenes, (higher substituted isomers)
Perylene
Phenanthrene
Phenanthrenes, (monomethylated isomers)
Phenanthrenes, (dimethylated isomers)
Phenanthrenes, (trimethylated isomers)
Phenanthrenes, (higher substituted isomers)
Pyrene
Pyrenes, (monomethylated isomers)

PAHs have low water solubility and high lipid solubility and may bioaccumulate in fish tissues (particularly the gills) and phytoplankton. Exposure to ultraviolet solar radiation greatly increases the toxicity of many of these PAHs. Those compounds with few aromatic rings (such as volatile BTEX compounds) are often acutely toxic when exposed to ultraviolet radiation, whereas compounds with many aromatic rings (PAHs) are chronically toxic when exposed to ultraviolet radiation. The amount of ultraviolet solar radiation and the depth of its penetration below the water surface also are factors effecting PAH toxicity.

LABORATORY METHODS

Volatile Organic Compounds

Because of the nature of VOCs, their determination is really only of significance in environmental water samples. The analysis has traditionally been performed by gas chromatography-mass spectrometry (GC/MS). A variety of sample separation or pretreatment methods have been used to enhance the sensitivity of the method. Conner and others (1998) reported on the use of a purge-and-trap separation procedure prior to GC/MS measurement for the determination of 86 VOC compounds in water. Gasoline oxygenated additives, such as MTBE, have also been determined by a solid-phase extraction technique (Achten and Püttmann, 2000; Cassada and others, 2000). More recently, Rose and Sandstrom (2003) have described a heated purge-and-trap/gas chromatography-mass spectrometric technique for the determination of gasoline oxygenates, selected degradation compounds, and the standard BTEX constituents with a sensitivity that yields a detection limit of about 0.1 µg/L.

The purge-and-trap method is suitable for the analysis of compounds that have a low solubility in water and a vapor pressure at 20°C of greater than 1 mm of Hg. Compounds having these properties can be quantitatively separated from a water solution by purging the sample with helium gas.

Semivolatile Organic Compounds—Polycyclic Aromatic Hydrocarbons

Sauer and Boehm (1991), have shown that methods recommended by the USEPA for the determination of semivolatile organic priority pollutants in oil-spill

assessments are inadequate for generating accurate scientific data for Natural Resource Damage Assessments, primarily because of chemical selectivity and sensitivity issues. Methods for the determination of compounds that are relatively insoluble in water and are readily extracted into an immiscible solvent, such as methylene chloride or hexane, are determined by a capillary column GC/MS technique preferably using a single-ion monitoring procedure for optimal sensitivity (Smith, 1999). USEPA drinking water Method 525.2, for the determination of PAH analytes, uses a solid-phase
C-18 cartridge for the isolation of analyte compounds followed by elution with methylene chloride prior to GC/MS analysis.

For sediment materials, USEPA method 8270c has often been used for analysis. In order to obtain satisfactory detection limits for the determination of low-concentration level PAH compounds and alkylated homologues (about 1 ng per g dry weight), a modification of the methodology is required. In some cases, a non-mass spectrometric method, such as size-exclusion high-performance liquid chromatography with fluorescence detection (Smith, 1999) can be effectively used to obtain adequate sensitivity.

Analytical methods for the determination of PAHs in SPMDs are similar in nature to those described above (Gustavson and Harkin, 2000; Kot and others, 2000). The methods for both VOCs and semivolatile organic compounds (SVOCs) which include PAHs, are typical multiconstituent methods that are currently used in most environmental chemistry laboratories. They are described for general informational purposes and are not intended to represent the state-of-the-art methodology. Most high quality environmental analytical chemistry laboratories that use multiconstituent high sensitivity techniques and adequate quality-control/quality-assurance protocols can provide satisfactory data for monitoring programs.

Because PAHs have low solubility in water, they are difficult to detect at very low concentrations with conventional laboratory analyses of water samples. In addition, in order to simulate the bioassimilation of these compounds in biota such as fish, mussels, and other organisms, the use of a passive sampling strategy is recommended. One such passive sampling approach is the use of a SPMD. Passive SPMDs are sampling devices used to sequester hydrophobic compounds from water and assess potential bioavailability during the duration of deployment (typically weeks to months). Passive SPMDs consist of a low-density polyethylene tube filled with a material that simulates fish lipid. A diagram showing the typical configuration of an SPMD can be found at http://www.exposmeter.se/. Compound concentrations in the SPMD are controlled by diffusion across the low-density polyethylene membrane; the diffusion is a function of the compounds in the water, the water temperature, the amount of time the SPMD is deployed, and biofouling of the membrane, which can impede diffusion.

SAMPLING METHODS

Stratification in reservoirs and lakes is caused by water temperature and chemical differences between the cooler and denser inflow waters and the warmer lake water. Each layer of the vertically stratified water column needs to be considered. A temperature and conductivity profile of the water column, as well as visual observation of reservoir samples, can often detect the different layers, which can be sampled separately. Dissolved oxygen, pH, specific conductance, and temperature are generally measured at each vertical depth. In lakes and larger impoundments where there is no vertical stratification a sample from the water column at a representative depth and at a given sampling location may be collected. Where there is stratification, the depths at which subsamples are taken are usually at the discretion of the field investigators. In some cases, it may be of interest to collect several separate samples at a specific depth, or composites of a range of depths of the epilimnetic and hypolimnetic zones (above and below the thermocline or depth of greatest temperature change).

Fine-grain sediment (less than 0.062 mm) deposited along beach faces, shorelines, and at marinas, from tributary inflow and overland runoff, are of greatest interest for sampling because of the hydrophobic character of PAHs. Also, major inflow areas such as the Colorado River form major sediment deltas where fine-grained sediments accumulate and hydrocarbon contaminants can be found. The tributary inflow patterns, reservoir circulation patterns, bathymetry, and reservoir shape need to be considered when selecting sediment-sampling sites.

Owing to the relatively low concentrations of dissolved solids (except at the immediate inflow of rivers and streams), collecting sufficient suspended sediment material for detailed chemical analysis will probably not be possible. An alternative would be to deploy sediment traps to collect a sufficient quantity of suspended matter having a particle size large enough to be deposited. This would discriminate against fine particle-size suspended material (clay/colloids), and would require integration over a significant time period (days or weeks).

The USGS has described and documented sampling and processing of surface water samples for VOCs (Shelton, 1994) for the National Water Quality Assessment (NAWQA) Program. Field methods that should be used for the collection of water from a reservoir or lake are described in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, 1999). In general, thief-type samplers should be used to collect water from the reservoirs as opposed to pumping samplers.

The collection and processing of bed-material samples is time-consuming and requires several steps in preparing the sample as described by the USGS (U.S. Geological Survey, 1999). Core or dredge-type samples should be used to collect a representative bed-material sample. The upper few centimeters of material should be the target for determining the presence of organic compounds (SVOCs) introduced by PWC or other gasoline-powered motor craft. Bed-material samples are often anaerobic in nature and, therefore, care must be given to process the sample in an oxygen-free environment.

Additional information for collection and processing is provided in USEPA, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (2001). Recommended use of appropriate blank and replicate samples are discussed in these references.

Special Precautions for Trace Contaminant Sampling

Contaminants are usually detected in the parts per billion and (or) parts per trillion range. Extreme care must be taken to prevent cross contamination of these samples. The following precautions shall be taken when trace contaminants are of concern:

1. A clean pair of new, non-powdered, disposable latex gloves need to be worn each time a different location is sampled, and the gloves should be donned immediately prior to sampling. The gloves should not come into contact with the media being sampled.
2. Sample containers for source samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collection of the sample.
3. If possible, pristine or potentially low-concentration level samples and source samples or samples suspected of containing high concentrations of contaminants should be collected by different field teams. If different field teams cannot be used, all pristine samples shall be collected first and placed in separate ice chests or shipping containers. Ice chests or shipping containers for source samples or samples suspected to contain high concentrations of contaminants shall be lined with new, clean plastic bags.
4. If possible, one member of the field sampling team should take all the notes and complete sample-bottle labels while the other members collect the samples.
5. When sampling surface waters, the water sample should always be collected before the sediment sample is collected.
6. Sample collection activities should proceed progressively from the least suspected contaminated area to the most suspected contaminated area.
7. Investigators should use equipment constructed of polytetrafluroethylene (PTFE), stainless steel, or glass that has been properly pre-cleaned for collection of samples for organic compound analyses. Equipment constructed of plastic or polyvinyl chloride (PVC) should not be used to collect samples for trace organic compound analyses.

After collection, all sample handling should be minimized. Investigators should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, investigators should ensure that melted ice cannot cause the sample containers to become submerged, as this may result in sample cross contamination. Plastic bags, sealed with tape, should be used when small sample containers (for example, VOC vials) are placed in ice chests to prevent cross contamination.

Special Handling of Samples for Volatile Organic Compounds (VOCs) Analysis

Water samples to be analyzed for VOCs should be stored in 40-mL septum vials with screw caps and PTFE-silicone disks in the caps to prevent contamination of the sample by the caps. The disks should be placed in the caps (PTFE side to be in contact with the sample) in the laboratory prior to the beginning of the sampling program.

The vials should be completely filled to prevent volatilization, and extreme caution should be exercised when filling a vial to avoid any turbulence, which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, the last few drops of sample should be poured into the vial so that surface tension holds the water in a convex meniscus. The cap is then applied with some overflow of the sample to prevent any air space in the bottle. After capping, the bottle is turned over and tapped to check for bubbles. If any bubbles are present, the procedure is repeated with another clean 40-mL vial. When collecting water samples for VOCs, three 40-ml vials should be filled with the sample.

Sampling for SVOCs (PAHs) in water generally requires the use of glass (Leenheer, 1984), PTFE or PTFE-coated equipment. Because of their lower volatility compared to VOCs, gas-tight sample containers and sample transfer devices are not required, although the devices used should be sealed to prevent or minimize the introduction of contaminants or the loss of water. Filtration of samples is generally not recommended because of potential loss of analyte compounds by adsorption on the filter media. Chilling the sample and analysis as rapidly as possible after sample collection can usually minimize loss of SVOCs by microbiological processes during sample storage.

MONITORING STRATEGIES

There are several factors that require consideration when evaluating various monitoring strategies for hydrocarbon contaminants (VOCs and SVOCs) associated with fuel-powered watercraft. Both the Glen Canyon NRA and Lake Mead NRA have information on sites where high-use boating is believed to occur in Lakes Powell, Mead, and Mohave, and this information was used in evaluating strategies. The proposed strategies presented in this section of the monitoring plan have considered the following factors:

1. State and Federal Water-Quality Standards for VOCs in drinking water.
2. USEPA's Water Quality Criteria for SVOCs (PAHs).
3. Effects on aquatic biota—growth, survival, morphology.
4. Fate and persistence of hydrocarbon compounds.
5. Timing of visitors to the lakes—summer versus winter, holidays versus non-holidays.
6. Visitor frequency, density, and accessibility—high-use areas where recreational boating is concentrated.
7. Limnological processes—when water column stratification occurs and seasonal variability.
8. Storm runoff events—episodic influx of suspended material such as sediments.
9. Basin influences—allochthonous (within the basin) and autochthonous (within the lake).
10. Reservoir morphology.
11. Monitoring costs, which include sample frequency and analytical costs.

All the factors listed above need to be considered when designing monitoring strategies. The morphological characteristics of Lakes Powell, Mead, and Mohave, however, strongly influence visitor density, use, and accessibility. The morphology of Lake Powell is considerably different than that of Lakes Mead and Mohave, primarily because of the geologic characteristics of the submerged Glen Canyon. Even though all three reservoirs are long and narrow, Lake Powell comprises more than 90 side canyon tributaries and has an irregular shoreline, which is conducive to recreational boating. Recreational boating in Lake Powell tends to be distributed throughout the reservoir in side canyons in the proximity of marinas (fig. 1). Lake Mead also consists of an irregular shoreline, but comprises smaller coves and bays. Boating activities tend to be concentrated near the Boulder Basin area in the lower reaches of the reservoir and in the Overton Arm (the Virgin River). Lake Mohave is small (length and volume) in comparison to Lakes Powell and Mead. It contains few coves or bays, and has a more regular shoreline.

Recreational boating is considerably greater during the summer months (May through September) on all three lakes and, therefore, the sampling for hydrocarbon contaminants should occur within this timeframe. Sampling during the low-visitor use season is required, however, in order to establish baseline data for VOC and SVOC constituents and to monitor changes in water quality related to boater activity.

Water-Quality Criteria

The USEPA sets Maximum Contaminant Levels (MCLs) established by the Safe Drinking Water Act, for approximately 90 contaminants in drinking water, which include 21 VOCs (U.S. Environmental Protection Agency, 2003; table 4). Ambient water quality of the Colorado River reservoirs may not be expected, however, to meet the MCLs. Drinking water standards have not been established for PAHs; however, the USEPA has established water quality criteria for the protection of human health for the consumption of priority toxic pollutants (U.S. Environmental Protection Agency, 2002; table 5). PAHs are highly associated with sediments in the water, they can bioaccumulate in the aquatic environment, and several are known carcinogens (for example, benzo(a)pyrene). These constituents will be included for analysis in the monitoring strategies. The presence of contaminants in Lakes Powell, Mead, and Mohave does not necessarily indicate that water poses a health risk.

Table 4. List of Maximum Contaminant Levels for drinking water for 21 volatile organic compounds (VOC)

[mg/L, milligrams per liter]

Compound	Maximum Contaminant Level, in mg/L
Vinyl chloride	0.002
Benzene	0.005
Carbon tetrachloride	0.005
1,2-Dichloroethane	0.005
Trichloroethylene	0.005
para-Dichlorobenzene	0.075
1,1-Dichloroethylene	0.007
1,1,1-Trichloroethane	0.2
Cis-1,2-Dichloroethylene	0.07
1,2-Dichloropropane	0.005
Ethylbenzene	0.7
Monochlorobenzene	0.1
o-Dichlorobenzene	0.6
Styrene	0.1
Tetrachloroethylene	0.005
Toluene	1.0
Trans-1,2-Dichloroethylene	0.1
Xylenes (total)	10
Dichloromethane	0.005
1,2,4-Trichlorobenzene	0.07
1,1,2-Trichloroethane	0.005

Table 5. List of 16 semivolatile organic compounds (polycyclic aromatic hydrocarbons; PAHs) and USEPA's recommended maximum consumption levels for human health

[µg/L, micrograms per liter; dashes indicate no data]

Compound	Water + Organism, in µg/L
Acenaphthene	670
Acenaphthylene	--
Anthracene	8,300
Benzo(a)anthracene	0.0038
Benzo(a)pyrene	0.0038
Benzo(b)fluoranthene	0.0038
Benzo(g,h,i)perylene	--
Benzo(k)fluoranthene	0.0038
Chrysene	0.0038
Dibenzo(a,h)anthracene	0.0038
Fluoranthene	130
Fluorene	1,100
Indeno(1,2,3-cd)Pyrene	0.0038
Naphthalene	--
Phenanthrene	--
Pyrene	830

Environmental Impact Statements—Preferred Alternatives

Environmental impact statements (EISs) prepared under the National Environmental Policy Act (NEPA) on the management and impacts of recreational boating, including PWCs on Lakes Powell, Mead, and Mohave, have been completed by both the GLCA and LAME for their respective parks. The Record of Decision (ROD) for the GLCA Final EIS was completed June 25, 2003 (http://www.nps.gov.glca/plan.htm). The preferred alternative described in the GLCA EIS for managing the use of PWC at Lake Powell allows the use of PWC identical to that before September 2002 under a special regulation. The preferred alternative allows the entire lake to be open to PWC use, except in areas where prohibited by the Superintendent's Compendium (National Park Service, 2003a). The prohibited areas and restrictions include:

1. From the mouth of the San Juan River upstream to the GLCA boundary.
2. The segment of the Colorado River downstream from (or south of) Glen Canyon Dam to the GLCA.
3. North or beyond mile marker 108 of the Colorado River and all tributaries, as measured from the

Glen Canyon Dam, to the boundary between the GLCA and Canyonlands National Park.

4. On the Escalante River upstream from Coyote Gulch.
5. Must be wakeless on the Escalante River from Cow Canyon to Coyote Gulch.

The ROD was published, and the Final Rule was made for Lakes Mead and Mohave on April 8 and 9, 2003, which determined implementing the modified preferred alternative (Alternative C) for use of PWC at LAME on Lakes Mead and Mohave (National Park Service, 2003b). The Final Rule allows for 95 percent of the lakes to remain open to PWC use. Alternative C allows for a slight increase in boater use and expansion of existing lake facilities. The alternative also prohibits the use of PWCs at the following areas:

1. Grand Wash Bay,
2. Bonelii and Gypsum Bays,
3. The confluence of the Virgin River in the Overton Arm of Lake Mead,
4. The confluence of the Muddy River down lake to the Overton Wildlife Management Area, and
5. The Black Canyon reach between Hoover Dam and Willow Beach Fish Hatchery during the period starting the second Tuesday following Labor Day through the Friday before Memorial Day.

There are no restricted areas on Lake Mohave from Willow Beach to Davis Dam.

The EISs specifically list VOCs including benzene, ethylbenzene, toluene, xylenes, and MTBE, and SVOCs including PAHs as particular concerns of PWC emissions. The concerns are relevant to the degradation of fish and aquatic organisms, livestock watering, drinking water, and recreation areas. The NEPA requires both GLCA and LAME to evaluate the impacts of PWC on water quality and other natural resources such as air quality and wildlife habitat.

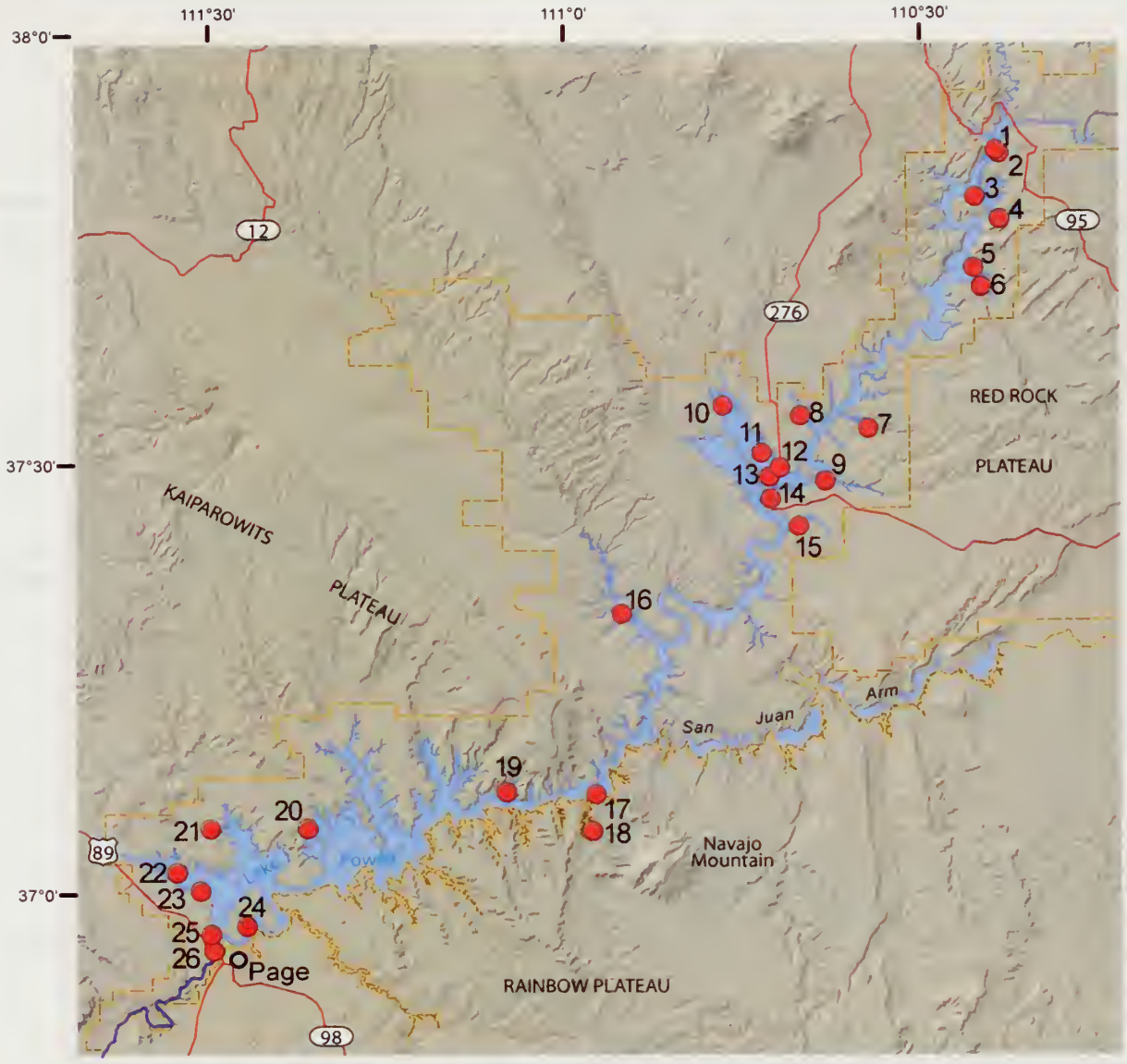
Provisional Site Selection—High Priority

High-priority sites (visitor-use zones) for monitoring at Lakes Powell, Mead and Mohave have been provisionally selected by Park resource scientists and managers. For the purpose of this plan, sites are categorized as: 1) Marinas, launch ramps, and drinking water intakes, and 2) coves, bays, side canyons, beaches, and mainstem reservoir (open water). For Lake Powell, 26 sites have been identified (table 6; fig. 2); for Lake Mead, 12 sites have been identified (table 7; fig. 3); and for Lake Mohave, 7 sites have identified (table 8; fig.4).

A reconnaissance-level survey of the high-priority sites should be made to make physical observations, determine logistical support needs for sampling trips, and to observe visitor-use activity and types and density of watercraft. Site information gathered from a reconnaissance survey will be used to make any necessary modifications to sampling at the proposed priority sites, or possibly to remove or add sites from the original lists.

Table 6. List of high-priority sites, Lake Powell

Marinas, launch ramps, drinking water intakes
1. Glen Canyon Dam Intake
2. Hite Water Intake
3. Hite Marina
4. Bullfrog Marina
5. Hall Crossing Marina
6. Dangling Rope Marina
7. Wahweap Marina
8. Stateline
9. Antelope Marina (future marina)
Coves, bays, side canyons, beaches, mainstem reservoir
10. Lone Rock
11. Crosby Canyon
12. Farley Canyon
13. Forgotten Canyon
14. Hansen Canyon
15. Moqui Canyon
16. Bullfrog north
17. Bullfrog south
18. Stanton Creek
19. Lake Canyon
20. White Canyon
21. Red Canyon
22. Blue Notch
23. Escalante Creek
24. Oak Creek
25. Rainbow Bridge
26. Gunsight Canyon



Explanation

Glen Canyon National Recreation Area

8 Sampling Site

Site Number	Site Name	Site Number	Site Name
1	Hite Marina	14	Hall Crossing Marina
2	Hite Water Intake	15	Lake Canyon
3	Farley Canyon	16	Escalante Creek
4	White Canyon	17	Oak Creek
5	Blue Notch	18	Ranbow Bridge
6	Red Canyon	19	Dangling Rope Marina
7	Forgotten Canyon	20	Gunsight Canyon
8	Hansen Creek	21	Crosby Canyon
9	Moqui Canyon	22	Lone Rock
10	Bullfrog North	23	Stateline
11	Bullfrog Marina	24	Antelope Marina
12	Stanton Creek	25	Wahweap Marina
13	Bullfrog South	26	Glen Canyon Dam Intake

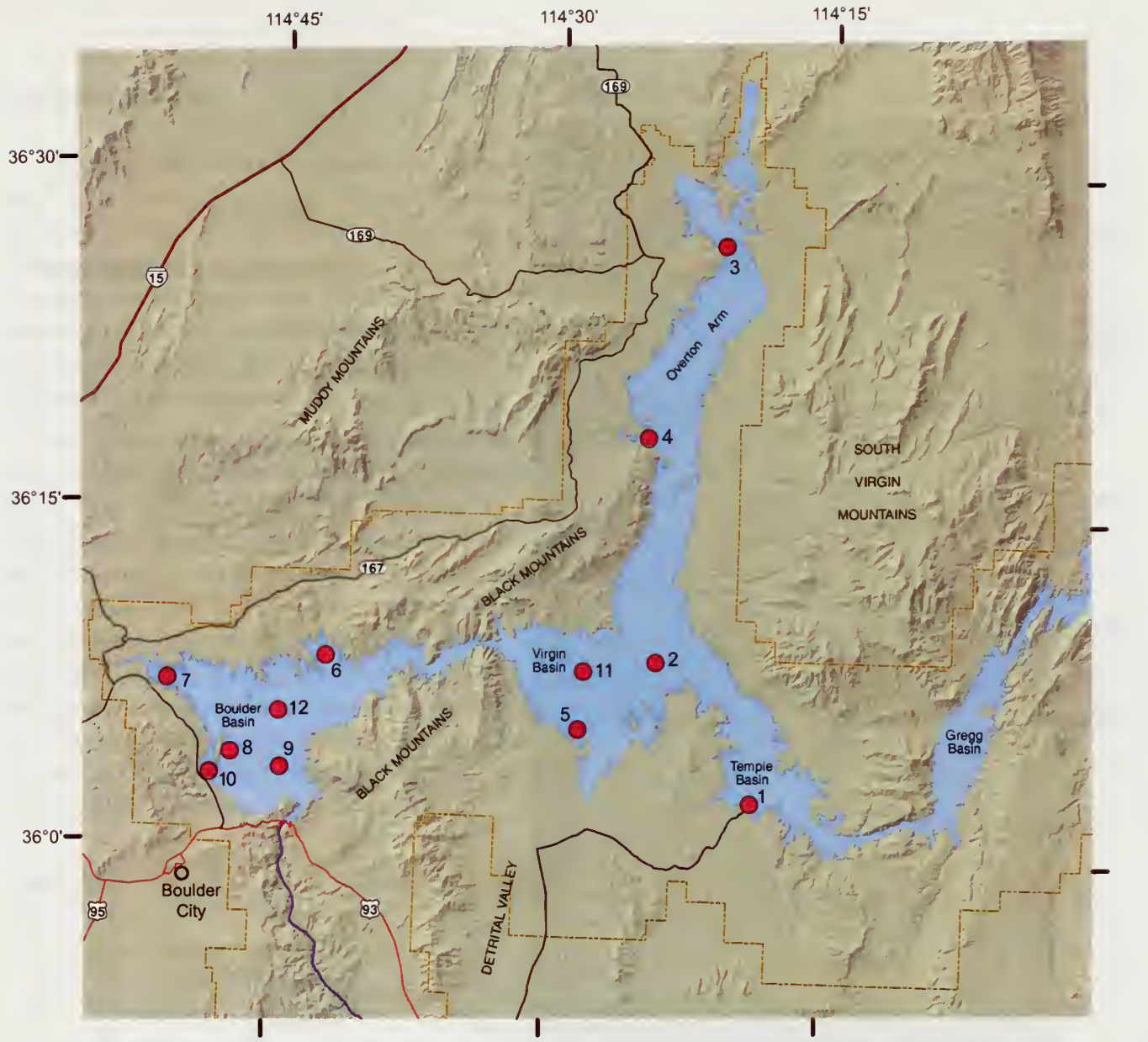
Figure 2. High-priority sites, Lake Powell.

Table 7. List of high-priority sites, Lake Mead

Marinas, launch ramps, drinking water intakes
1. Temple Bar
2. Overton Beach Area
3. Echo Bay
4. Callville Bay
5. Las Vegas Bay
6. Saddle Island
7. Sentinel Island
8. Lake Mead Marina
Coves, bays, side canyons, beaches, mainstem reservoir
9. Historic confluence of the Colorado and Virgin Rivers
10. Bonelli Bay
11. Mid-Virgin Basin
12. Mid-Boulder Basin

Table 8. List of high-priority sites, Lake Mohave

Marinas, launch ramps, drinking water intakes
1. Willow Beach
2. Nelson's Landing
3. Cottonwood Cove
4. Katherine
Coves, bays, side canyons, beaches, mainstem reservoir
5. Mohave Crossing
6. Nevada Telephone Cove
7. Mid-Cottonwood Basin



Explanation

Lake Mead National Recreation Area

8 Sampling Site

Site Number	Site Name
1	Temple Bar
2	Mouth of the Virgin River
3	Overton Beach
4	Echo Bay
5	Bonelli Landing
6	Callville Bay
7	Las Vegas Bay
8	Saddle Island
9	Sentinel Island
10	Lake Mead Marina
11	Mid-Virgin Basin
12	Mid-Boulder Basin

0 10 20 Miles

0 10 20 Kilometers

Figure 3. High-priority sites, Lake Mead.

Figure 4. High-priority sites, Lake Mohave.

Monitoring Options

The monitoring options presented in this plan are based on the physical media with which contaminants are known or suspected to be associated, including: (1) the water column, (2) suspended sediment or bottom sediments, and (3) biota. VOCs, if present, will be detected in the water column, whereas SVOCs will be associated more with the sediment material in suspension or bottom material.

Four options for monitoring contaminants in the water column are presented in table 9. The presence of SVOCs in bottom material and in biota samples is proposed to be sampled at the same locations as water samples defined by the four options. Two monitoring seasons, the high-use season and the low-use season, are suggested for monitoring and are based on the timing of visitor use and on reservoir stratification. The high-use season occurs between Memorial Day (late May) through Labor Day (early September). The low-use season occurs following the Labor Day holiday through the Friday before Memorial Day.

Water-Column Sampling

Water samples will be collected for all options during both the high-and low-use seasons (table 9). During the high-use season, samples should be collected monthly (four times: June, July, August, and September) beginning immediately following the Memorial Day holiday and ending the week following the Labor Day holiday. This sampling frequency covers the most heavily used periods at all reservoirs. During the low-use season, only one sampling trip is required, but the timing should be consistent from year to year. Unlike the high-use period, only shallow samples should be collected during the low-use season. The low-use season sampling is to provide background data for comparison to data from the high-use season.

The USGS recently documented the use of LakeVOC, a deterministic model that estimates the concentrations of VOCs in lakes and reservoirs (Bender and others, 2003). A model of this type could be used to estimate the concentrations of VOCs in the epilimnion and the hypolimnion, and the total mass of VOCs in those layers in Lakes Powell, Mead, and Mohave using the monitoring sampling options described in this plan.

Table 9. List of water column monitoring options for Lakes Powell, Mead, and Mohave

	Water column sampling														
	Lake Powell					Lake Mead					Lake Mohave				
	High Use Season (Memorial Day through Labor Day)														
Options	Marinas, ramps, intakes		Beach areas	Coves, bays, side canyons, mainstem		Marinas, ramps, intakes		Beach areas	Coves, bays, side canyons, mainstem		Marinas, ramps, intakes		Beach areas	Coves, bays, side canyons, mainstem	
	Shallow	Deep	Shallow	Shallow	Deep	Shallow	Deep	Shallow	Shallow	Deep	Shallow	Deep	Shallow	Shallow	Deep
A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B			X	X	X			X	X	X			X	X	X
C	X	X				X	X				X	X			
D	See discussion on option D in following section.														
	Low-use season (Following Labor Day through the first Friday before Memorial Day)														
A	X		X	X		X		X	X		X		X	X	
B			X	X				X	X				X	X	
C	X					X					X				
D	See discussion on option D in following section.														

Option A: All Priority Sites

This option is the most comprehensive of the options proposed and is the preferred option because all priority sites are monitored. Provisional site selection includes 42 different areas in Lakes Powell, Mead, and Mohave that should be included in the initial monitoring plan. As shown in table 9 and described previously, both shallow and deep samples should be collected for analysis.

Option B: Coves, Bays, Side Canyons, Beach Areas, and Main Stem Reservoir

Option B is a reduction in sampling sites from 42 sites in option A to 21 sites and provides an alternative cost model for the monitoring plan. This option focuses on sampling sites in coves, bays, side canyons, beach areas, and the mainstem of the reservoir, but does not include marinas, launch ramps, or drinking-water intakes (option C discussed below). As with option A, both shallow and deep samples will be collected for laboratory analysis during the high-use season, and from shallow depths during the low-use season. The same sampling frequency during the high- and low-use seasons as described in option A will be used for option B.

Option C: Marinas, Launch Ramps, and Drinking-Water Intakes

Because there is a high probability of contamination from watercraft use at the marinas and launch ramps, option C is presented as an alternative low-cost model for option A, but consists of the same number of sites as option B. This option also includes sampling in the vicinity of drinking-water intakes at all reservoirs. Option C, however, will not provide information on areas where visitors are congregating for water-sport activity. As with options A and B, the sampling approach will be the same during the high- and low-use seasons. There are 21 sites to sample for this option (table 9).

Option D: Subset of High-Priority Sites

This option is presented for consideration for sampling a subset of the 42 provisional high-priority sites (option A) and also would provide representation of sites described in options B and C. NPS scientists and managers would determine the subset of sites. As described with the other options, the sampling approach would be designed around the high- and low-use seasons, and collecting samples from shallow and deep depths. Option D is a lower-cost monitoring option for consideration but also could be used to implement a plan to rotate sampling sites on an annual basis or at some other scientifically justifiable frequency.

Bottom-Sediment Sampling for Semivolatile Organic Compounds

The monitoring plan suggests sampling for SVOCs from bottom material at sites defined in options A, B, C, and D (table 10) following sampling methods described in the sampling methods section of this plan. For monitoring purposes, an annual sampling plan is sufficient to determine the presence and changes in SVOCs at selected sites. For comparison purposes, it is suggested that the sampling of SVOCs should be consistently done during the same month of each year.

Table 10. Bottom sediment sampling options for Lakes Powell, Mead, and Mohave

	Bottom sediment sampling								
	Lake Powell			Lake Mead			Lake Mohave		
Options	Marinas, ramps, intakes	Beach areas	Coves, bays, side canyons, mainstem	Marinas, ramps, intakes	Beach areas	Coves, bays, side canyons, mainstem	Marinas, ramps, intakes	Beach areas	Coves, bays, side canyons, mainstem
A	X	X	X	X	X	X	X	X	X
B		X	X		X	X		X	X
C	X			X			X		
D	See discussion on option D under monitoring options.								

Biota Sampling

The deployment of SPMDs in Lakes Powell, Mead, and Mohave for the determination of potential bioaccumulation of SVOCs (PAHs) by biota should be given careful consideration because of the costs associated with the method. Important criteria that need to be considered when deploying the SPMDS include aquatic habitat, comparability to various fish species, and duration of deployment. NPS aquatic ecologists who are knowledgeable about the habitat and fish species of the individual reservoir should be consulted. The general location of deployment, however, is suggested to coincide with a subset of the bottom-material sampling options shown in table 10.

Monitoring Costs

Monitoring costs for this plan vary depending on the monitoring strategy option that is selected by the NPS. Because of the sizes of Lakes Powell, Mead, and Mohave, the logistical costs associated with visiting priority sites will be substantial and will vary depending upon whether the NPS manages the monitoring plan in-house or contracts the work to another Federal agency or private company. As mentioned previously, sample processing for VOC and SVOCs analyses is time-consuming, and this labor-intensive activity will substantially affect the cost of the monitoring plan. Also, the analysis of organic compounds is expensive, particularly that for SVOCs in bottom-material samples. Another factor that is important in any monitoring plan is an adequate quality- assurance program that supports the validity of the sampling methods and laboratory analyses. Table 11 presents a range in analytical costs based on the USGS price structure at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. The table is presented to provide readers with an idea of costs associated with laboratory analysis of organic constituents.

Contingency Plans for Accidental Spillage

Intense use of motorized watercraft on Lakes Powell, Mead, Mohave, and the Colorado River, during the summer months, present situations for major accidents that could involve spillages of gasoline, gasoline additives, and oil. Additionally, older watercraft engines and 2-stroke engines emit non-combusted gasoline and oil during normal use.

Gasoline contains compounds (BTEX) and additives (MTBE) that are known to have toxic effects on aquatic life and human health. Should an accident occur on these lakes that involves gasoline and oil spillages, there is a possibility that some coves, bays, side canyons, public beaches, and open water that are used for recreational purposes and contact sports, could be rendered off limits to the public. Should an accident occur at boat launch ramps, gas stations, boat docks, or other major populated locations, the area would need to be evacuated as a precaution for explosions. Safety of the recreational people would be the first concern.

The first respondents to arrive at the scene of an accident most likely would be the NPS, the Arizona Game and Fish Department, and the Utah Division of Wildlife Resources on Lake Powell, the Arizona Game and Fish Department, and the Nevada Division of Wildlife on Lakes Mead and Mohave. As part of their first response and emergency protocols, trained NPS personnel and Arizona and Nevada State personnel would help assess and monitor the aerial extent of the spill by description and photography.

Table 11. Relative annual net costs associated with laboratory analysis for monitoring options A, B, C, and D, in thousands of dollars

[Note: 1) Costs are based on 2004 USGS laboratory prices; 2) costs are for all three lakes based on proposed options]

	Option A	Option B	Option C	Option D
Water	115–120	58–63	58–63	Some fraction of Option A
Bottom material	45–50	22–27	22–27	Some fraction of Option A
Biota	Some fraction of Option A	Some fraction of Option A	Some fraction of Option A	Some fraction of Option A
Quality assurance[1]	11.5–12	5.8–6.3	5.8–6.3	Some fraction of Option A

[1]Quality assurance plan suggests 10 percent of the samples collected for field and lab replicates and blanks.

These personnel also would have in their possession the necessary sampling equipment, bottles, preservatives, gloves, and field notes to collect water samples for analyses of VOCs. These samples would be maintained on ice until collected by the entity responsible for monitoring.

The area of the spill would be restricted from recreational use by NPS law enforcement, and the spill would be surrounded by flotation devices to keep it confined from lateral spreading. Areas of the lakes which support threatened and endangered aquatic life would be sampled and monitored should spillages occur at or near those areas, as would areas at or near water-supply intakes. It may be necessary to secure these areas until cleanup is accomplished.

The entity responsible for monitoring would assume responsibility for assessing the spill and collecting water samples. Water samples for VOCs analyses should be collected, and the spill site monitored until it has been completely cleaned up. Water samples collected from an accident at a lake site should be collected at the surface and at several depths below the surface to provide vertical concentration information. Additionally, samples would be collected moving outward away from the accident to provide concentration information on spatial dispersion. A zone of potential contaminant movement should be defined by NPS, and the monitoring entity and sampling sites within this zone should be defined. Throughout the water collection activities, depth profiles of water temperature, specific conductance, pH, and dissolved oxygen should be measured.

The collection of bed-material samples and deployment of SPMDs could be considered. Analysis for SVOCs from these samples could be used for determining the longer-term effects of the spill. Water, bed material, and biota should be monitored at downstream sites from accidental spills that occur in tributaries to the lakes. Laboratory analyses of water, bed material, and biota would vary based on the nature of the spill.

Management, Evaluation, and Analysis of Data

The NPS uses Microsoft ACCESS for management of data. It is suggested that this database system be used for the management of data for the monitoring plan. Data should be analyzed on an annual basis and results should be presented at annual meetings with GLCA and LAME. On a schedule determined by the NPS, a more rigorous evaluation of data should be made. The evaluation should include trend analysis and eventually statistical analysis when an adequate database is populated. The evaluation and analysis should also determine whether the existing data-collection plan is adequate and the appropriate constituents are being analyzed. Laboratory methods are constantly improving and, therefore, new methods should be considered for implementation. Also, the NPS may want to consider publication of data in an NPS report or other publication outlet for distribution.

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